



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.08.2005 Bulletin 2005/31

(51) Int Cl.7: **B61K 9/08, B61K 9/12,
B61L 23/04, G01M 17/10**

(21) Application number: **04425060.3**

(22) Date of filing: **02.02.2004**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR**
Designated Extension States:
AL LT LV MK

(72) Inventor: **Ghislanzoni, Luca**
23900 Lecco (IT)

Remarks:
Amended claims in accordance with Rule 86 (2)
EPC.

(71) Applicant: **C-Sigma s.r.l.**
23900 Lecco (IT)

(54) **Apparatus and method for detecting wheel-flats, axle bearings eccentricity and rail-track defects in a railway system**

(57) The apparatus measures the output signals of conventional toothed-wheel type rotational rate sensors, and it processes them in order to extract measurements of a "jitter parameter". In typical applications, a minimal amount of jitter noise is always present. However, jitter levels differing significantly from said background noise are indication of wheel-flats or rail-track defects, the former being correlated to the periodicity of

a complete wheel revolution, and the latter to the vehicle's speed and inter-axle distances through the time delay measured between detections on separated axles. Furthermore, comparisons of "jitter parameter" measurements, recorded at different times, allow the monitoring of the evolution in time of bearings eccentricity and defects, a very useful preventive diagnostics feature. The apparatus can also be used in automotive and industrial machinery applications.

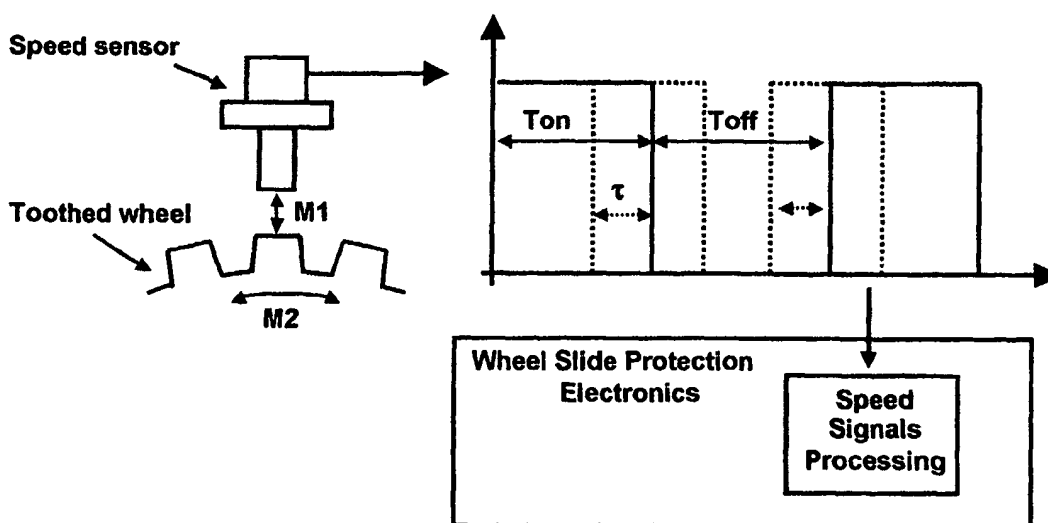


Fig. 1A

BEST AVAILABLE COPY

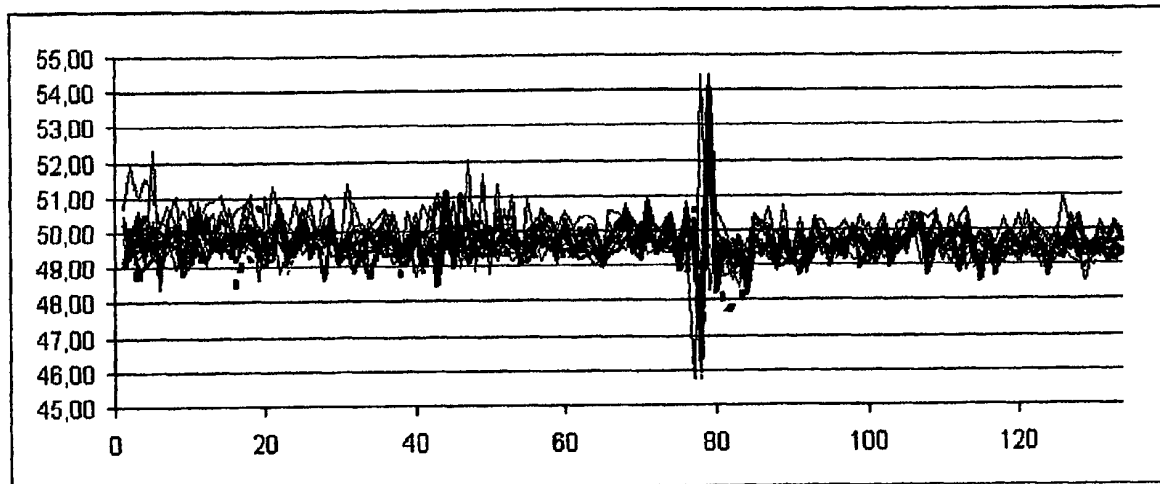


Fig. 1B

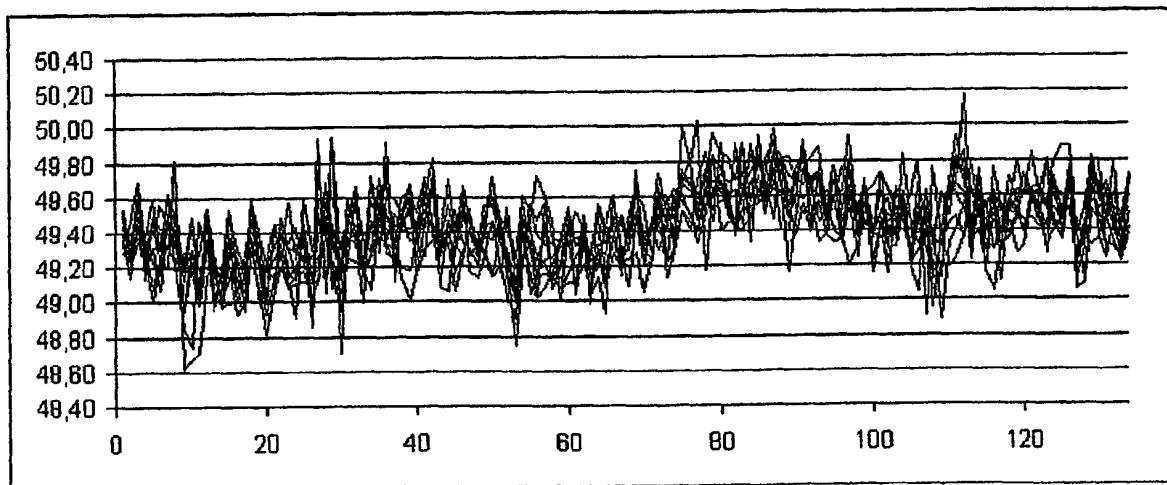


Fig. 1C

Description

[0001] The present invention describes a method and an apparatus to detect wheel flats in railway vehicles, allowing at the same time the monitoring of the evolution of axle bearings eccentricity and defects, as well as the detection of "sharp" rail track defects (excessive gaps and the like).

[0002] Several devices are commercially available which already feature similar functions, although obtained by other means. Most notably, many devices belonging to the previous art rely on the use of vibration sensors, such as accelerometers. The output signals from such accelerometers are then processed and correlated to the wheel-set's rotation rate, with the aim to detect characteristic "signatures" on the signals, and which appears only at the occurrence of said defects. An important example of such previous art is detailed in General Electric Company's US patent n. 5,433,111.

[0003] However, this type of devices are usually of very expensive implementation, requiring that an additional apparatus, and sensors, are purchased and installed on the vehicle.

[0004] The present invention, instead, obtains similar diagnostics capabilities by introducing a novel way to process and filter the speed signals already available to the Wheel Slide Protection (WSP) Electronics (a sort of ABS for railway vehicles). No accelerometers or additional devices are required, other than the already present speed sensors and WSP Electronics, which shall now be designed to implement the method described herein.

[0005] WSP electronics apparatuses are widely used on railway type brake equipments to prevent wheel lock conditions, which could be very damaging for the wheel-set. Their use is controlled and prescribed by international standards (UIC, International Union of Railways).

[0006] It shall be remarked that the assignee of this invention, C-Sigma srl, is a manufacturer of railway type WSP Electronics apparatuses, and plans to embed this novel feature in all its future models.

[0007] Although this invention is ideally suited for implementation in WSP electronics apparatuses, it can obviously be embodied also in other types of apparatuses, and in particular in self-contained devices. For example, the person skilled in the art can easily imagine ways to implement this method directly into a "smart" speed sensor.

[0008] The inventive step of this invention consists in combining conventional toothed-wheel sensors with the capability to measure and record the jitter modulation on their output signals.

[0009] Processing, and display by suitable means, of the recorded jitter measurements, allows then the detection of the defects described above. Figure 1A illustrates the basic principle of the invention. Speed sensors conventionally used in railway applications make use of magnetic or inductive sensing elements to detect

the passage of the teeth of a ferro-magnetic toothed-wheel, which is mounted on the axle of the wheel-set. Some type of sensors generate sinusoidal output signals, some other include also amplification and zero-crossing detection circuitry (squarer circuit), as to directly generate a square wave output signal. When using a sinusoidal output type of sensor, the WSP Electronics usually includes a squarer circuit, or any other of the techniques well known to the skilled in the art, so as to allow the measurement of the frequency of the sensor's output signal. From the frequency value, it is then possible to compute the vehicle's speed, and monitor the rotation rate of each axle (typically, one WSP electronics controls 4 axles).

[0010] Said n the number of teeth, d the wheel's diameter, and f the frequency of the speed sensor's output signal, then the vehicle's speed, V , is related to f by the following equation:

$$V = f \pi d / n \quad (1)$$

[0011] Figure 1A depicts also the effect resulting from the onset of the following vibration or disturbance modes:

- Radial Mode M1, which results in small variations of the gap between the sensor's reading head and the toothed-wheel.
- Peripheral Mode M2, which results in small variations of the relative speed between the sensor's reading head and the toothed-wheel.
- Orthogonal Mode, along the direction orthogonal to M1 and M2, but less important because variations along this direction do not significantly modify the jitter modulation (the corresponding tooth dimension is larger than the sensor's reading head).

[0012] These vibration modes are, in turn, triggered by shocks and-or vibrations due to defects of the wheel (wheel-flats), and-or bearings, and-or rail track. Their net effect on the output signal is the presence of jitter, indicated with the greek letter tau, τ , in fig. 1A. Jitter is defined as a modulation of the pulse-width of the output signal. So that, by watching for example said output signal on an oscilloscope, and setting the trigger point on the rising edge, we would notice continuous small variations of the instant at which the falling edge occurs.

[0013] If we define the duty cycle as, $T = T_{on} + T_{off}$:

$$\alpha \% = 100 \cdot T_{on} / T \quad (2)$$

and which, for an ideal square wave, is nominally 50%. The presence of vibration or disturbance modes M1 and-or M2 will result in a small modulation of $\alpha\%$.

[0014] A minimal amount of jitter is unavoidable, and it will always be present due to manufacturing toleranc-

es, and various other sources of background noise. In a typical application said minimal modulation is usually contained within $\pm 1\%$, around a nominal value of $\alpha \% = 50\%$.

[0015] Apparatuses of the previous art disregard this modulation as merely one more source of noise, being only interested in the measurement of the frequency of the speed sensor's output signal.

[0016] On the contrary, this invention does not disregard this source of noise, but it includes specific means to accurately measure its value and periodicity of occurrence, with the declared aim to obtain precious diagnostics information about defects of the wheels, bearings, rail track.

[0017] Figure 1B clearly illustrates the detection of a wheel-flat condition. The data shown correspond to recordings made on a tram vehicle, and which had a flat on the wheel-set whose speed sensor output signal was being monitored. Figure 1B is actually the superposition of 10 graphs, each graph showing the measured value of $\alpha \%$ (vertical axis) for each one of the consecutive pulses counted (horizontal axis). As one pulse corresponds to one tooth, and the number of teeth was in this case $n = 134$, the horizontal axis spans from 1 to 134 counts. So, the first complete wheel revolution corresponds to graph 1, after teeth 134 has passed by the sensor's head, the $\alpha \%$ value of the next pulse is assigned to graph 2, and starting again at position 1 to end at position 134, ... and so on ... till the completion of graph 10. Figure 1B contains hence the measurements of $\alpha \%$ for a total of 1340 consecutive pulses (i.e.: 10 consecutive wheel's revolutions). In this way it becomes very easy to visually compare variations in $\alpha \%$, and when they occur with respect to the periodicity of a complete wheel revolution (134 teeth). This particular sequence of wheel revolutions was recorded while the vehicle was accelerating from about 2 Km/h to about 10 Km/h. It can be observed how the variations of $\alpha \%$ are mostly contained within $\pm 1\%$, however all the 10 graphs show a large spike; up to $\pm 4\%$, at the same position on the wheel (on the graphs, between tooth 78 and 79). This spike is the characteristic "signature" of a flat wheel condition. In principle the recording of just one complete wheel revolution shall suffice to identify said characteristic "signature", however, to rule out possible spurious noise it is better to verify whether it also occurs with the same periodicity as that of a complete wheel revolution. So, it is advisable to record the measurements for at least 2 consecutive wheel revolutions (i.e.: for the case of a toothed-wheel with $n = 134$, a minimum of 268 consecutive measurements).

[0018] A defect on the rail track consisting in an excessive gap between two adjacent segments of track, would also generate a similar spike. In such case, the spike will be a one-off occurrence (hence, with no correlation to the periodicity of a wheel revolution), but appearing on the output signals of all the 4 sensors monitored by one WSP Electronics. The time intervals be-

tween the occurrence of said 4 spikes will depend on the vehicle speed, and on the distance between the 4 axles. When such a defect is detected, its location on the rail track can be reconstructed if the corresponding odometer value is recorded. At the next vehicle halt date and time are recorded, as well as the distance to the detected defect. The vehicle's journal shall then allow to reconstruct the approximate location of the defect. Alternatively, a more accurate way would record the geographical coordinates as generated by a GPS receiver module.

[0019] Figure 1C also shows the superposition of 10 graphs, corresponding to 10 consecutive wheel revolutions, but for a wheel-set with no damage. As no damage is present, no large spikes are observable. Even in this case it appears very clear that the small modulations (of $\alpha \%$) follow a pattern with the periodicity of a complete wheel revolution. This small modulations are due to manufacturing tolerances and mounting eccentricity. By comparing the recordings carried out at various times during the service life of the vehicle (let's say for example every 100000 Km), it is possible to monitor the evolution of axle bearings' defects or wear. This is a very useful feature for optimising preventive maintenance schedule.

[0020] Referring to the possibility to automatically detect characteristic "signatures" (spikes, and the like), the person skilled in the art could imagine several possible algorithms for their automatic detection. A typical example would be based on the definition of thresholds for deviations from average values, their time durations, and their correlation to a wheel revolution. However, this invention is not concerned with the particular choice of detection algorithms, therefore in the following we will assume that such an algorithm can be implemented in the apparatus, although we will make no reference to particular choices. When needed, we will generically refer to said detection threshold values as to "characteristic signatures detection thresholds". A typical apparatus embodying the invention would be composed of:

1. A conventional speed sensor with associated toothed-wheel.
2. A Speed Signals Processing circuit, easily realised by means of squarer circuits (for the measurements shown in Figures 1B and 1C, were the speed sensors themselves that already generated square output signals) feeding the CAPTURE input of a micro-controller (nowadays, most industry standard micro-controllers feature CAPTURE inputs). The CAPTURE input is used to measure the values of **Ton** and **Toff**, so as to allow the computation of $\alpha \%$. In the prototype of the new C-Sigma WSP Electronics, **Ton** and **Toff** are measured with $1\mu s$ resolution.
3. A section of memory in which to store said measurements $\alpha \%$. In the prototype measured values are stored in RAM as the difference with respect to

$\alpha\% = 50\%$. This allows to shrink each measurement into a single 8 bits memory location.

4. Means to display said measurements, such as a graphic display, as it is the case for the new WSP Electronics of C-Sigma. Said measurements could also be made available (in addition, or in alternative) to an interface to external devices. Indeed, the prototype also allows the choice (accessible from a menu on the front panel display of the new WSP Electronics of C-Sigma) to send said measurements to the front panel RS232 or CAN interfaces, for continuous monitoring, display, and-or recording, on external apparatuses (such as, for example, a portable PC).

[0021] Those skilled in the art will appreciate that several other useful features could be added, but which are of obvious derivation. An example is the addition of a user's choice for the speed range at which to start the recording of the $\alpha\%$ measurements, or a choice for recording from the instant a button is pressed, and the like. Other examples include the addition of a modem to allow remote monitoring of the $\alpha\%$ measurements, or the reception of remote SMS requests to respond with reply SMSs containing said $\alpha\%$ measurements, and the like.

[0022] Indeed, also these solutions are possible with the assignee's existing WSP Electronics, which includes a plug-in board featuring a standard GSM-GPRS modem, and in addition a GPS module, useful to rely information about the location of detected rail track defects.

[0023] Furthermore, several ways can be imagined to implement algorithms, directly in the software running on the micro-controller, which could automatically recognize the characteristic "signatures" corresponding to the various defects, to then generate alarm flags and-or alarm signals of various type.

[0024] It could also turned out useful to compare measurements of complete wheel revolutions, though this time NOT consecutive, for widely different speed values. This can be obtained by waiting, without recording, an integer number of complete wheel revolutions, before starting to record again when the next required speed value is reached. Alternatively, on the toothed-wheel, one or more teeth could be machined differently from all the others, and in a way to generate values of $\alpha\%$ (for example 60%) easily recognizable from the mean value. Example: among a sequence of $n-1$ pulses with $\alpha\% = 50\%$ suddenly appears a pulse with $\alpha\% = 60\%$, as in the sequence:

50%, 50%, 50%, 50%, 50%, 60%, 40%, 50%, 50%, 50%,

[0025] The position of the 60% value can then be use as a reference to allow a meaningful superposition also of graphs recorded at different dates (once every few months, once a year, etc.).

[0026] Such a trick allows to detect also the sense of rotation. In fact, by monitoring the sequence:

Ton/T, Toff/T, Ton/T, Toff/T, Ton/T, Toff/T,

[0027] With the rotation in one sense the Speed Signals Processing will at some point measure **Ton/T=60%**, immediately followed by **Toff/T=40%**. For the rotation in the other sense the Speed Signals Processing will *before* measure **Toff/T=40%**, and immediately *after* **Ton/T=60%**.

[0028] Although Figures 1B and 1C depicts the superposition of graphs representing $\alpha\%$, it shall be obvious to those skilled in the art that other equivalent representations are of direct derivation, such as: **Toff/T, Toff/Ton, Ton/Toff**, etc.

[0029] Other effective representations consist in plotting directly the value of τ , computed as the difference **Ton - <Ton>** (where **<Ton>** indicates the mean value over n pulses), or **Toff - <Toff>**, or **Ton - Ton(1)** (where **Ton(1)** indicates a reference value measured only once per revolution, or twice, etc.), **Toff - Toff(1)**, and the like.

[0030] Indeed the number of possible ways to represents the effect of jitter is quite high, and the skilled in the art could find several reasons to prefer one way rather than another. To make the following description independent from the particular choice of jitter representation, we will collectively refer to any of the possible choices as to a generic "jitter parameter".

[0031] Furthermore, each representation can be analysed with reference to different types of coordinates:

- Spatial coordinates, when the chosen reference points are spatial positions, such as, for example, the teeth count used in fig. 1B and 1C.
- Time coordinates, when reference is time, and characteristics spikes are correlated with the wheel's rotational rate.
- Frequency coordinates, when a transform (e.g.: Fourier, Z, Laplace, etc.) is applied to the recorded values, as to allow an analysis in the frequency domain, with correlations to the fundamental frequency defined by the wheel's rotational rate.

[0032] The inventive step of this invention shall be understood as independent from the particular choices of "jitter parameter" representation and reference coordinates, rather it consists in the idea to implement means to enable monitoring, recording, and comparisons on said "jitter parameter", whatever the choice for its representation.

[0033] Although the above description and examples refer to the application of the invention to the railway field, its application could be advantageous also in the automotive field, in particular for its capability to monitor defects and wear of bearings. More in general, this invention can be applied to all those applications (industrial machinery, etc.) where the combination toothed-wheel + sensor is used to monitor and/or measure rotational rates.

[0034] It shall be appreciated that those skilled in the art, building on the features of the invention described above, now could easily imagine many changes, modi-

fications, and-or substitutions. The following claims are intended to cover all such changes as fall within the spirit of the inventive step detailed in the above description.

Claims

1. Apparatus **characterised in that** it combines and processes, by means of a microprocessor or micro-controller, the output signals of wheel revolution sensors (such as conventional toothed-wheel sensors) with the measurement of a "jitter parameter" on said signals, to detect and monitor flats on railway wheels, defects and wear of bearings, defects on rail track. The detection of flats is achieved by verifying, visually or automatically, that spikes (i.e.: values clearly standing out of the average "jitter parameter" value) on graphs such as those of fig. 1B appear at integer multiples of a complete wheel's revolution. Said verifications can be made at a preferred range of the vehicle's speed and-or at several different speed values. The monitoring of the evolution of defects and wear in bearings is achieved by comparing, visually or automatically, graphs such those of fig. 1C, recorded at different times. Said comparisons can be made for a preferred range of the vehicle's speed and-or for several different speed values. To ease the comparison of measurements recorded at different times, a reference spike could be artificially introduced by machining in suitable ways one or more teeth, as detailed in the description. The detection of rail-track defects is achieved by verifying, visually or automatically, that spikes on graphs such as those of fig. 1B appear sequentially on all monitored speed signals, and with a time sequence defined by the vehicle's speed and by the distance between the axles on which the respective speed sensors are mounted. Although the listed capabilities refer to applications in the railway industry, it shall be apparent to those skilled in the art that said capabilities are of relevance also to automotive applications, as well as to industrial machinery applications.
2. An apparatus as claimed in Claim 1, **characterised in that** a front panel display presents to the user one or more of the following choices: real time monitoring on a display of the "jitter parameter"; real time monitoring and/or recording on an external device of the "jitter parameter"; selection of speed values at which to start the recording of the "jitter parameter", for a selectable number of complete wheel revolutions; selection of the number of complete wheel revolutions to record and/or analyse; selection of "characteristic signatures detection thresholds" for the automatic generation of alarms when characteristic signatures appear. The above choices could also be made selectable from external devices, con-

nected to the apparatus via industry standard interfaces (such as, for example: RS232, RS485, CAN bus, MVB bus, PROFI bus, etc.).

3. An apparatus as claimed in Claim 1 and Claim 2, **characterised in that** a modem (very practical are GSM type, but also other types are possible) is added to allow remote real time monitoring of said "jitter parameter", as well as logging on a Central Server. Periodic comparisons, carried out on the logged data by a diagnostic module of the software running on said Central Server, will then allow the detection of defects and/or wear, as well as the monitoring of their evolution in time. Said modem remote connection could also be used to allow remote selection of the choices listed in Claim 2. The use of GSM modem would also allow the implementation of Central Server requests via SMS messages, to which the apparatus could reply also with SMS messages.
4. An apparatus as claimed in Claim 3, **characterised in that** a GPS receiver module is added, as to allow accurate reporting on the exact location of detected rail-track defects.
5. An apparatus as claimed in Claim 1, **characterised in that** the described functionalities are implemented directly into the speed sensor. Such a "smart sensor" would also feature the possibility to monitor in real time "jitter parameter" values on external devices, such as PCs, PDAs, User Terminals, and the like. The selection of choices, such as those described in Claim 2, could, also in this case, be made selectable from external devices, connected to said "smart sensor" via industry standard interfaces (such as, for example: RS232, RS485, CAN bus, MVB bus, PROFI bus, etc.).

Amended claims in accordance with Rule 86(2) EPC.

1. A method to detect and monitor flats on railway wheels, defects and wear of bearings, defects on rail track, using only rotational rate sensors without requiring accelerometers or other additional devices;
characterised in that
said method is arranged for
 - using conventional toothed wheel sensors to generate pulses whose frequency is proportional to the rotational speed;
 - measuring not only the frequency of said pulses, as it is done in devices belonging to the previous art, but also the time duration of ON and OFF intervals for each single pulse, and with sufficient time resolution to detect jitter on said pulses;

- processing said measurements in order to compute a "Jitter Parameter" representing the small variations in pulse width, as for example, among the other several possible equivalent mathematical techniques detailed in the description, the Duty Cycle $\alpha \% = 100 * Ton / T$, which represents a very simple and computationally effective technique; 5
- recording said single pulse measurements and/or computed "Jitter Parameter" for a number of pulses corresponding to a complete wheel revolution, as a minimum, but also up to any multiple of such number; 10
- processing such recorded data to detect unusual values of said "Jitter Parameters" by suitable methods, such as for example the graphs shown in figures 1B and 1C, correlating said data to the periodicity of complete wheel revolutions; 15
- allowing the comparison of data recorded at different times, such for example every year, every million Km, and the like, and in order to monitor the evolution of bearings wear; 20
- allowing also the automatic detection of said defects, through the implementation of optimised automatic analysis algorithms, such as for example algorithms based on threshold detection of spikes of the type depicted in figures 1B, or algorithms monitoring the evolution of the standard deviation of "Jitter Parameters" distribution, and the like. 25 30

2. Apparatus implementing the method described in Claim 1, comprising:

one or more rotational rate sensors, such as a conventional toothed-wheel sensors, and a microprocessor or microcontroller;

characterised in that

the rotational rate sensors are mounted and arranged for generating an output signal proportional to the vehicle's speed, and said output signal is then properly conditioned, before being made available to the microprocessor, by means of any of the standard interfacing techniques known to the skilled in the art: squaring when needed, introducing galvanic isolation when needed, level adapting when needed, and the like; 40 45

said microprocessor, or microcontroller, is arranged for 50

- capturing said signal from said rotational rate sensors, so as to measure the time duration of the ON and OFF intervals of the pulses of said signal; 55
- computing, for each of said pulses, a representative "Jitter Parameter", such as for example

the duty cycle $\alpha \% = 100 * Ton / T$;

- detecting the presence of spikes similar to those depicted in figure 1B, by comparing the last computed value of said "Jitter Parameter" with an average value computed on a subset of all previous value, such as for example the average computed over a complete wheel revolution;
- correlating the appearance of said spikes on the signals from more than one sensors to the vehicle's velocity and the distance between the axle's monitored, in order to detect defects on the rail-track;
- storing said ON and OFF intervals measurements and/or "Jitter Parameter" values for each one of the pulses corresponding to a complete wheel revolution, or multiple thereof;
- providing means for downloading said recorded data to an external processing and displaying device, such as for example a portable personal computer, and the like.

3. A device as claimed in Claim 2, characterised in that

the toothed wheel used by the rotational rate sensor is further arranged to ease the comparison of measurements recorded at different times, by means of a reference spike, artificially introduced by machining in suitable ways one or more teeth, as detailed in the description.

4. A device as claimed in Claim 2, characterised in that

a user front panel with small keyboard and display is added to allow the user

- a real time monitoring, on said display, of said "jitter parameter";
- the selection of speed values at which to start the recording of the "jitter parameter", for a selectable number of complete wheel revolutions;
- selection of the number of complete wheel revolutions to record and/or analyse;
- selection of "characteristic signatures detection thresholds" for the automatic generation of alarms when characteristic signatures appear.

5. A device as claimed in Claim 2, characterised in that

the real time monitoring, and selection options listed in Claim 4 are further accessible via an industry standard data interface, such as for example RS232, RS485, CAN bus, MVB bus, PROFi bus, and the like.

6. A device as claimed in Claim 2, characterised in that

a modem, such as for example the very practical

GSM type, is added, and it is arranged for

- allowing remote real time monitoring of said "jitter parameter";
- allowing the logging on a Central Server of the sent data, as to allow periodic comparisons by means of a diagnostic module within the software running on said Central Server, and with the purpose to remotely detect defects and/or wear, as well as the monitoring of their evolution in time;
- allowing the remote selection of the selection options listed in Claim 2, via any one of the several suitable techniques known to the skill in the art, such as for example: SMS messages, GSM data connection, GPRS internet connection, and the like.

- making use of the speed signals already available to the ABS Brake Controller;
- exploiting the data processing and handling capabilities of the ABS Brake Controller;
- monitoring the standard deviation of the "Jitter Parameters" distribution's, so as to monitor, and-or detect, wear and defects of axle's bearings;
- allowing the download of recorded data to external devices, so that maintenance technicians can compare graphs of the type shown in figure 1-C, recorded at different times, in order to monitor the evolution of bearings eccentricity.

7. A device as claimed in Claim 2, characterised in that

a GPS receiver module is added, to allow accurate reporting on the exact location of detected rail-track defects.

8. A device as claimed in Claim 2, characterised in that

said microprocessor or microcontroller is implemented directly into the toothed wheel sensor, as to obtain a so-called "smart sensor", and it is arranged for

- allowing the real time monitoring of "jitter parameter" values on external devices, such as PCs, PDAs, User Terminals, and the like, and via an industry standard interface, such as, for example: RS232, RS485, CAN bus, MVB bus, PROFI bus, etc.;
- allowing the selection of choices, such as those described in Claim 4, from said external devices, and via said industry standard interfaces.

9. Apparatus implementing the method described in Claim 1, characterised in that

said method is naturally embedded into a railway type of Wheel Slide Prevention Electronics, and it is further arranged for:

- making use of the speed signals already available to the Wheel Slide Prevention Electronics;
- exploit the data processing and handling capabilities of the Wheel Slide Prevention Electronics.

10. Apparatus implementing the method described in Claim 1, characterised in that

said method is naturally embedded into an automotive type of ABS Brake Controller, and it is further arranged for:

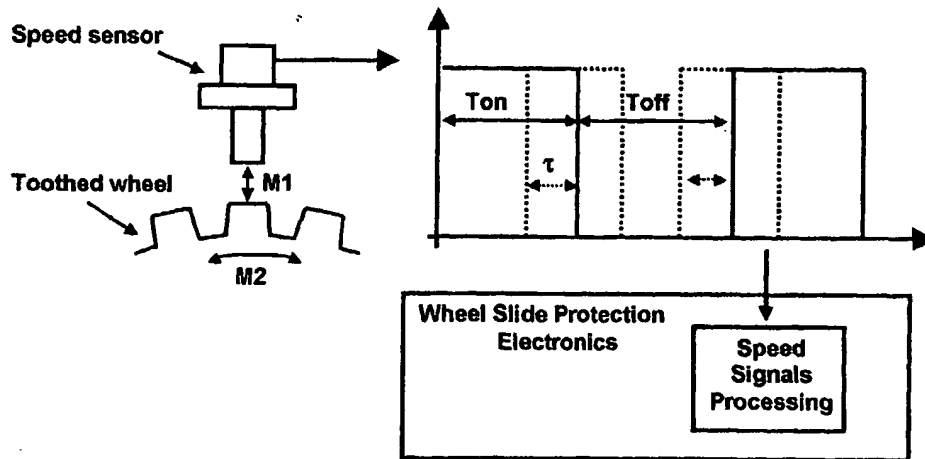


Fig. 1A

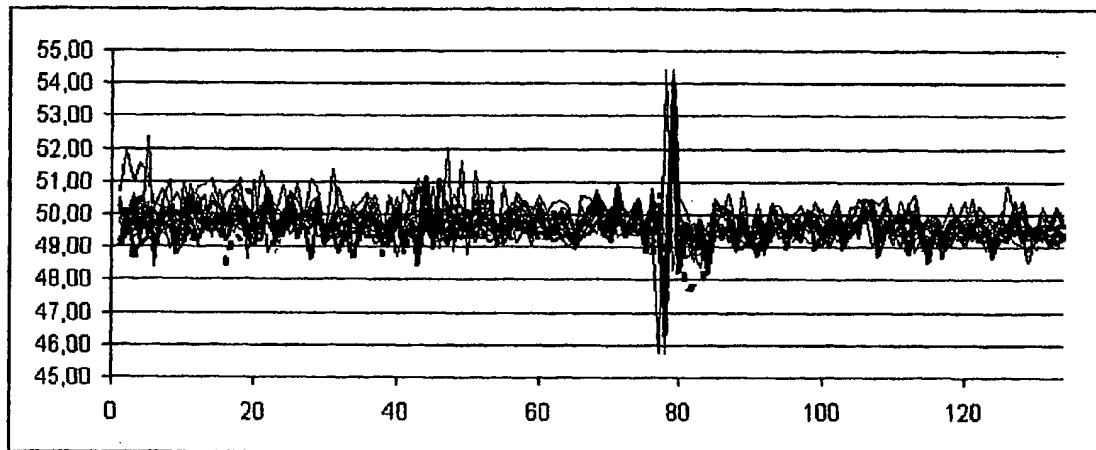


Fig. 1B

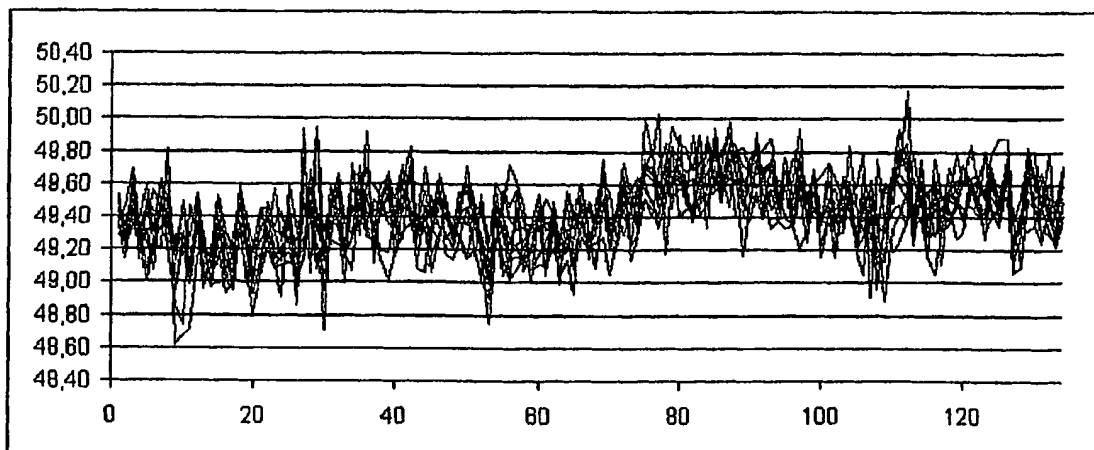


Fig. 1C



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 42 5060

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	DE 198 27 271 A (MUELLER ANDREAS ; WEIDER DIETMAR (DE)) 23 December 1999 (1999-12-23) * paragraph [03.2] * * column 10, lines 30-37 * * claim 1 *	1	B61K9/08 B61K9/12 B61L23/04 G01M17/10
A,D	US 5 433 111 A (HERSHEY JOHN E ET AL) 18 July 1995 (1995-07-18) * abstract; figures *	1	
A	DE 198 35 041 C (WERNER MICHAEL) 5 August 1999 (1999-08-05) * the whole document *	1	
A	US 2003/231014 A1 (MORETTI ET AL.) 18 December 2003 (2003-12-18) * abstract; figures *	1	
A	CH 668 129 A (STABEG APPARATEBAU GMBH) 30 November 1988 (1988-11-30) * the whole document *		TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	DE 100 20 519 A (DEUTSCHE BAHN AG) 31 October 2001 (2001-10-31) * abstract; figures *		B61K B61L G01M G01B G01P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 11 August 2004	Examiner Ferranti, M
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

1
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 42 5060

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-08-2004

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
DE 19827271	A	23-12-1999	DE	19827271 A1	23-12-1999
US 5433111	A	18-07-1995	CA	2163626 A1	16-11-1995
			DE	19580682 T0	26-09-1996
			JP	9500452 T	14-01-1997
			WO	9530886 A1	16-11-1995
DE 19835041	C	05-08-1999	DE	19835041 C1	05-08-1999
US 2003231014	A1	18-12-2003	NONE		
CH 668129	A	30-11-1988	CH	668129 A5	30-11-1988
			AT	67386 A	15-05-1990
DE 10020519	A	31-10-2001	DE	10020519 A1	31-10-2001
			AU	5630601 A	07-11-2001
			WO	0181147 A1	01-11-2001
			EP	1278673 A1	29-01-2003

THIS PAGE BLANK (USPTO)

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)